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ABSTRACT

Past studies have shown that, although older adults are more likely than young adults to fail various concrete operational tasks, age differences on these tasks can be eliminated through short-term training. To test the trainability of formal, rather than concrete, operations college students (N=27) were compared with older adults (N=27). Performance on a modified version of Piaget's equilibrium-in-a-balance task divided subjects into one of three training conditions: rule plus feedback, feedback, and no feedback. A comparison of pre-test and post-test performance indicated that both young and elderly adults could use the formal operations solution rule when it was provided, but subjects' successful use of the rule did not produce positive transfer on other formal operations tasks. Simple feedback on performance produced no noticeable improvement among either young or elderly adults. Results suggest the use of formal operations is tied less to age than to experiential and health variables. (NRB)

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Trainability of Formal Operations in Adulthood

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Since the publication during the early seventies of the first reports of adult age differences in performance on concrete operations problems, there have been numerous studies of the course of concrete and formal operations during adulthood. Results of some cross-sectional studies show that older adults are more likely than young adults to fail such concrete operational tasks as conservation of weight, substance, and area (e.g., Papalia, 1972; Rubin, Attewell, Tierney, and Tumulo, 1973; Clayton and Overton, 1976). Yet other studies provide evidence that age differences on these tasks can be eliminated through short-term training (e.g., Hornblum and Overton, 1976).

The present research was initially focused on the trainability of concrete operations in adulthood in order to address the disparate results of existing research. We planned to contrast minimal feedback training previously demonstrated to be successful in overcoming performance problems (Hornblum and Overton, 1976), with verbal rule instruction training, which has been credited with restructuring cognitions during the transition to concrete operations (Beilin, 1965). The relative effectiveness of the two training procedures was intended to provide an indication of whether elderly adults' poor conservation performance reflected transient situational problems or age-linked regression in cognitive competence. However, we soon encountered a significant problem. Our mid-Missouri sample of young and elderly adults all passed our tests of

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concrete operations on initial testing; thus, they could demonstrate no improvement as a function of training. We then shifted our attention to the trainability of formal operations, since our sample showed poor performance on formal operations reasoning tasks.

As Edith Neimark (Note 1) recently observed, formal operations is not a disease, whose presence or absence is detectable by means of a simple diagnostic test or set of tests. It is a hypothetical construct within Piaget's theory of genetic epistemology and undoubtedly one of the more hotly contested aspects of the theory. There has been wide acceptance of the emergence during adolescence of properties of thought that are included in the label formal operations but vigorous challenges of the utility of the system of logical structures described by Piaget for characterizing everyday thinking in adolescents and adults.

Why then another study of formal operations in adulthood? The focus of the present research was not to address the appropriateness of formal operations as a description of adult intelligence, but rather to use the formal operations tasks to investigate the trainability of scientific thought at different adult age levels. The tasks serve as a useful vehicle because they focus on subjects' abilities to isolate relevant variables and formulate hypotheses about problem solution. In particular, we were interested in age and cohort differences in the ability to induce a solution rule from informative feedback.

The following questions were addressed in the present research:

- 1) Are there age-cohort differences in the ability to use informational feedback in the induction of a formal operations solution rule?
- 2) Are there age-cohort differences in the application of a formal operations solution rule if such a rule is provided to subjects?

3) Does training on one formal operations task generalize to others?

4) What is the relationship between education, health status, and performance on formal operations tasks?

The design of the present research was a $2 \times 3 \times 2$ factorial with young and elderly adults, three degrees of training, and pre- and post-test performance measurements. Participants in the young adult group were 27 college students at the University of Missouri--Columbia who participated for class credit or a cash bonus. Older adults were 27 community-dwelling residents of Columbia, Missouri, paid for their participation, who were contacted through newspaper ads and through sign-up sheets in the city's two senior housing projects. The data from two elderly subjects was not included in the analysis, one of whom was recovering from cataract surgery, and one on medication for hypertension. The mean age of the young and elderly adults was 21.07 and 72.41 years respectively. Young adults had more years of schooling than older adults, 14.26 for the young adults and 12.52 for the older adults, respectively, a difference that was significant ($t(52)=2.72$ $p<.05$). Young adults also reported better health than older adults on a 4-point rating (Mann-Whitney U test, $z=2.72$ $p<.01$). The relationship between education, health status and task performance will be discussed later.

All subjects were tested individually in an hour-long session at the psychology building on the University of Missouri campus. Subjects were first assessed on conservation of area and displacement volume in a sequence including two different deformations and a check trial. All subjects passed the area task and 89% of the young and elderly subjects passed the volume task, with no significant differences between age groups. Because of this high initial level of performance, conservation of volume was dropped from the training battery, since subjects could show little improvement from initially ceiling levels of performance.

In the formal operations pretest, subjects were presented with a modified version of Piaget's equilibrium in a balance task. Blocks were placed under both arms of a balance scale and subjects were asked to predict which direction the scale would tip or whether it would remain in balance with different uneven arrangements of weights on each side. There were three problems on the balance task: one problem simply tested subjects' understanding that distance from the fulcrum affected equilibrium, and two problems were set up so that weight and distance cues were in conflict. On one test the correct prediction was that the scale would tip toward the side with more weight and on the other the correct prediction was that the scale would tip toward the side where the weight was further away from the fulcrum. The projection of shadows task required subjects to predict the relative size of two shadows as their distance from each other and a light source was systematically varied. A third task, Motion in an Inclined Plane, asked subjects to make predictions about the countervailing forces acting on a weight in equilibrium. For each of these tasks there were three problems in which subjects were asked to predict the effect of a change that altered the proportional relationship among the elements.

Subjects who had missed one or more of the balance problems were assigned to one of three training conditions, all of which involved ten problems on the equilibrium in a balance task. Subjects in the rule + feedback condition were given visual feedback on their balance predictions--the blocks supporting the two sides of the balance were removed and the subject observed whether or not the action of the scale conformed to their predictions. In addition, after an incorrect prediction, they were given a solution rule--a simple cross-products

rule where the numbers of weights on each side is multiplied by the number of units it is from the center, with the results summed for each side and the two sums compared.

Individuals in the feedback condition were allowed to see whether the scale would actually tip in the direction they had predicted or remain balanced, without being given any rule information, and individuals in the no feedback control condition were shown the ten problems, and asked to make predictions without ever being given feedback on the correctness of their responses. Immediately after the training trials, subjects were given the post-test with new problems on the same three tasks they had been pre-tested, with no feedback on their performance. Finally, they were asked a series of questions about their educational background.

Pre-test and post-test results were analyzed with non-parametric tests because of the limited range of scores and non-normality of variance. Mann-Whitney U tests were used to evaluate age and condition differences and Wilcoxon signed ranks tests were used to evaluate within-subject changes from pre-test to post-test (Siegel, 1956). The broader range of scores during training on the balance tasks permitted the use of analysis of variance.

As illustrated in Table 1, of the four tasks initially assessed, the conservation of volume, equilibrium in a balance, projection of shadows, and motion in an inclined plane, only the projection of shadows showed initial age differences in performance ($z=2.67$, $p<.05$). The correlation between the amount of education and shadows task performance for the older group proved significant ($r=.49$, $p<.05$), but similar correlations between education and performance on the inclined plane task and the balance task failed to attain significance (r 's $\leq .16$). Although there were significant age differences in self-rated health mentioned earlier,

correlations between older adults' health ratings and their performance on each of the formal operations tasks proved non-significant (r 's $\leq .20$).

On the ten-trial balance training task, there was a significant difference between conditions on an analysis of variance with the rule-instructed group producing the highest number of correct predictions ($F(2,48) = 7.92$, $MS_e = 2.03$, $p < .01$); there was no difference in the scores of the two age groups ($F < 1$), nor was there an age by condition interaction. Perhaps the most surprising outcome was that the feedback condition showed slightly poorer performance than did the no-feedback control condition. Thus, there were no age differences in the ability to utilize a formal operations solution rule, nor in the ability to induce a rule through feedback on predictions--both age groups were uniformly successful at the former task and uniformly poor at the latter one. It had been anticipated that subjects would be able to use feedback to improve their predictions from pre-test to post-test with the provision of visual feedback on their predictions but as is evident in Table 1 this did not occur for either the young or the elderly adult group.

When pre-test and post-test performance was compared, the initial age differences on the projection of shadows task mentioned earlier also showed up on the post-test ($z = 3.04$, $p < .01$), but there was no significant change from pre-test to post-test in either the young or the elderly adult group. Thus, there was no indication that the rule-instructed subjects showed any significant benefit of training on the balance task which generalized to this task. On the inclined plane task there were no initial age or condition differences (z 's ≤ 1.09) and the direction of change from pre-test to post-test was positive but non-significant in all three conditions.

To briefly summarize the results, we observed that both young and elderly adults could make use of a formal operations solution rule when it was provided

to them, but the illustration of such a rule and subjects' successful application of it did not produce positive transfer on other formal operations tasks. Simple feedback on performance produced no noticeable improvement in performance of either young or elderly adults.

This study is consistent with the findings of other research which shows a demonstrably different pattern of age-relatedness for the formal operations tasks, notably research by Sabatini and Labouvie and Vief (Note 2). The results of the training procedure are also consistent with the work of Tomlinson-Keasey (1972) who attempted to train formal operations in three groups of women with mean ages of 11, 21, and 54 years of age. Like Tomlinson-Keasey, we found a significant training effect, but no generalization of training sequence. This seems to suggest that within formal operations there are qualitatively different logical structures. These operations appear more loosely related than logical operations that comprise concrete operations, since the successful generalization of training of concrete operations was not duplicated in the current research.

The present research provides one more bit of evidence for the notion that the use of these thought structures labeled formal operations is tied less to age itself than to experiential and health variables. On one of the two tasks where significant age differences were observed, we also observed significant correlations between pre-test performance and education. Years of schooling differed between age groups, but it is perhaps even more important to note the age and cohort differences in content of education. Older subjects had much less science education--less math, less chemistry, less physics, so even cross-age matching on number of years of schooling may not equate for cohort differences in the quality of educational experience.

In the present study, the presentation of simple feedback on the correctness or incorrectness of responses to experimenter-formulated problems was insufficient to produce lasting change in the formal operations being trained. The success of the rule-instruction training was clearly limited in that it produced little cross-task generalization in formal operations. What type of training could produce positive transfer? The successful training procedure is probably going to be one in which subjects are exposed to three or more formal operations tasks so that the behavior of separating the variables and active experimenting towards a solution by the subject becomes decontextualized, that is, separated from a particular set of materials or procedures used in any one portion of training. Several training sessions, rather than one session used in the present research, may be necessary to achieve the desired improvement.

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Reference Notes

1. Neimark, E.D. Formal operations is not a disease. Paper presented at the Society for Research in Child Development Meetings, San Francisco, 1979.
2. Sabatini, P., Labouvie-Vief, G. Age and specialization in formal reasoning. Paper presented at the Gerontological Society Meetings, Washington, D.C., 1979.

Table 1. Mean Pretest and Post-test Scores of Rule Instruction + Feedback, Feedback, and No Feedback Control Conditions

YOUNG ADULTS (Mean Age = 21.07, SD = 4.21)

	Pretest		Rule + Feedback Condition (N = 9)		Post-test		No Feedback Control Condition (N = 9)	
	All Three Conditions (N=27)				Feedback Condition (N = 9)			
	M	SD	M	SD	M	SD	M	SD
Equilibrium in a Balance	1.44	.93	2.78	.44	1.22	.83	1.78	.44
Projection of Shadows	2.52	.89	2.78	.44	2.77	.44	2.22	1.20
Motion in an Inclined Plane	2.44	.75	3.00	.00	3.00	.00	2.77	.44

ELDERLY ADULTS (Mean age = 72.41, SD = 6.75)

	Pretest		Rule + Feedback Condition (N = 9)		Post-test		No Feedback Control Condition (N = 9)	
	All Three Conditions (N = 27)				Feedback Condition (N = 9)			
	M	SD	M	SD	M	SD	M	SD
Equilibrium in A Balance	1.52	.75	2.11	.78	1.67	.71	1.78	.66
Projection of Shadows	1.70	1.06	1.67	1.41	1.88	.99	1.67	1.00
Motion in an Inclined Plane	2.15	.95	2.33	.50	2.11	1.05	2.89	.33

Note: Maximum score on each task = 3.